UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII (8EPR-PS)
999 18th STREET - SUITE 300
DENVER, COLORADO 80202-2466

Region VIII

1074148

MEMORANDUM

SUBJECT: Fibrous Amphibole Contamination in Soil and Dust at Multiple Locations in Libby Poses an Imminent and Substantial Endangerment to Public Health: an Addendum to my Memorandum of May 10, 2000

FROM: Christopher P. Weis, Ph.D., DABT.
Science Support Coordinator
Libby Asbestos Site

TO: Paul Peronard, On-Scene Coordinator
Libby Asbestos Site

I PURPOSE

This memorandum presents the rationale for determination of imminent and substantial endangerment to public health from asbestos contamination in soil and soil-like material at multiple locations in and around the community of Libby, Montana. With this memorandum I confirm and extend a similar conclusion derived in a previous memorandum from my office to you dated May 10, 2000. The May 10 memorandum includes background and site conceptual information important for conclusions and recommendations presented herein.

II SUMMARY OF FINDINGS

1) Asbestos material is present in soil, raw ore, ore concentrate and other soil-like materials at multiple locations in and around the community of Libby. This asbestos material is primarily a friable amphibole containing a series of closely related minerals including actinolite, tremolite, winchite and richterite. Asbestos fibers of this type are known to be hazardous to humans when inhaled.

2) Mechanical disturbance of asbestos-contaminated soil or related materials by activities similar to those that are likely to be performed by area residents or workers results in elevated levels of respirable asbestos fibers in air. The concentrations of these fibers in air frequently exceed OSHA guidelines, and estimated excess cancer risks can exceed EPA's typical guidelines by an order of magnitude or more in some cases.

3) On this basis, it is concluded that soils and other similar materials that contain elevated levels of friable asbestos minerals are a likely source of on-

going release of hazardous fibers to air, and that it is necessary to reduce or eliminate pathways of exposure of this material to residents and workers.

III BACKGROUND

Vermiculite was discovered in the Rainy Creek Mining District of Lincoln County, Montana in 1916 by E.N. Alley. Alley formed the Zonolite Company and began commercial production of vermiculite in 1921. Another company, the Vermiculite and Asbestos Company (later known as the Universal Insulation Company), operated on the same deposits (BOM, 1953). W.R. Grace purchased the mining operations in 1963 and greatly increased production of vermiculite until 1990 when mining and milling of vermiculite ceased.

Vermiculite ore bodies on Zonolite Mountain are associated with amphibole asbestos concentrations ranging up to nearly 100% in selected areas (W.R. Grace). Although early exploration and mining efforts by the Zonolite Company focused upon the commercial viability of fibrous amphibole deposits found on Zonolite Mountain (DOI, 1928) no commercial production of asbestos from the Libby mine is reported. During early mining operations airborne fiber concentrations at the mine exceeded 100 fibers/cc in several job classifications (Amandus et al, 1987). Historical airborne fiber concentrations in the residential area of Libby exceeded the present occupational Permissible Exposure Level (PEL) of 0.1 fiber/cubic centimeter established by OSHA 1994 (MRI, 1982; Eschenbach deposition). This exposure limit is recognized as being associated with significant risk (3.4 additional asbestos-related cancers per 1000 individuals as per OSHA estimates) but is the practical lower limit of detection using phase contrast microscopy (PCM) as a measurement technique (OSHA, 1994).

Residual fiber contamination from the subject facilities continues to present potential exposure to workers, residents, and visitors at these facilities but is presently being addressed under removal authorities provided in the Comprehensive Environmental Response Compensation and Liability Act Section 104 (CERCLA or Superfund). These actions by the U.S. Environmental Protection Agency Region 8 office in Denver, CO began on November 22, 1999 and continue today. The investigative team is working closely with Local, State, and other Federal Agencies to determine the nature and extent of mineral fiber contamination throughout Libby, and to take appropriate action to protect the health of current residents and workers.

IV ENDANGERMENT RATIONALE

The rationale for determination of imminent and substantial endangerment is four-fold:

1) Asbestos fibers from the Libby mine site are hazardous to humans as evidenced by the occurrence of asbestos-related disease in area workers and residents. Workers exposed to asbestos fibers at the Libby mine site have been shown to experience clear and significant increases in the incidence of asbestos-related conditions, including asbestosis, lung cancer and mesothelioma. Asbestos-related lung diseases

among have also been observed in area residents with no direct occupational exposures, including family members of mine workers, and even in those with no known association with the vermiculite mining or processing;

2) Asbestos fibers can be detected in soil and/or related materials at multiple locations around the community. These contaminated materials constitute a potential source of asbestos exposure of area residents and workers;

3) Asbestos fibers in contaminated soil or related material may be released into air by a variety of activities similar to those that area residents or workers may engage in under normal living and working conditions. This demonstrates that a complete exposure pathway exists by which asbestos-contaminated source materials may cause inhalation exposure of area residents or workers;

4) The concentrations of asbestos fibers that occur in air following mechanical disturbance of contaminated soil or dust have been found to often exceed: a) OSHA guidelines for the protection of workers during an 8 hour workday (0.1 f/cc) and during excursion events (1 f/cc for 30 minutes), and b) EPA's guidelines regarding acceptable lifetime excess cancer risks for both residents and workers.

Summaries of the evidence supporting each of these elements of rationale are presented below.

1. Libby Asbestos Fibers Are Hazardous to Human Health (Hazard Assessment)

Evidence of the adverse effects from exposure to asbestos fibers associated with the vermiculite ore body on Zonolite Mountain is abundant. During the 1980s, MacDonald et al. (1986 a,b), and Amandus et al. (1987a,b,c) conducted investigations of asbestos exposure, and the morbidity and mortality of workers involved in various aspects of vermiculite mining, milling and refining processes in Libby, MT. These investigations found that workers had significantly increased occurrence of asbestosis, lung cancer, mesothelioma, and asbestos-related pleural disease associated with exposure to the vermiculite. Additionally, increased asbestos-related lung abnormalities were found among workers at an expansion plant in Marysville, Ohio, that were exposed to vermiculite from the Libby mine, Lockey et al. (1984).

Since the cessation of vermiculite mining and processing operations in Libby, local physicians and nearby pulmonary specialists have continued to identify individuals suffering from asbestosis, lung cancer and mesothelioma as a result of exposure to asbestos mineral fibers . One board-certified pulmonologist has reportedly seen over 150 cases of asbestos-related disease from the Libby area (Whitehouse, 2000). In addition to former mine workers, this physician reported striking findings of asbestos-related disease among household contacts of former workers and among area residents with no identifiable connection to the former mine or processing activities. Some of those area residents with asbestos-related disease and no connection to the mining operations were reportedly exposed to vermiculite through activities such as playing in open piles near recreational parks, gardening, and contact with home insulation. Reports by area physicians are supported by recent morbidity and mortality assessments of Libby residents conducted by the Agency for Toxic Substances and Disease Registry (ATSDR). A mortality study for Libby area residents from 1979 to 1998, found increased rates of asbestosis (40-60 times higher than the normal background rate for the United States) and mesothelioma (ATSDR 2000). Additionally, ATSDR, USPHS, and EPA conducted a medical testing program from July through November, 2000, of over 6000 individuals that worked or lived in Libby for at least six months prior to 1991. Preliminary analysis of data from over 1000 of the medical testing participants indicated that overall about 20% had chest x-ray abnormalities (identified by at least 2 of 3 B-readers) consistent with asbestos exposure (ATSDR, 2001). Of note, almost 40% of those identified with chest x-ray abnormalities had no occupationally-related vermiculite exposures. Asbestos-associated radiologic abnormalities, similar to those observed among medical testing participants in Libby, have been shown in other populations to be associated with significant progression of disease, morbidity, and mortality (Miller, 1983; Cookson, 1986; Rosenstock, 1991; Erlich, 1992; Hillerdal, 1997).

2. Asbestos Fibers Occur in Soil and Dust at the Site (Source Characterization)

EPA has collected samples of dust, soil, and other soil-like materials at numerous locations in and around the mine site and the community of Libby. In accord with common practice, examination and evaluation of these materials was performed using polarized light microscopy (PLM), as detailed in the *Sampling and Quality Assurance project Plan (Revision 1) for Libby, MT* (USEPA, 2000). Example results are shown in Table 1. As seen, concentrations of asbestos as high as 10-15% have been detected in some materials. Even though some samples do not contain asbestos levels that are detectable by PLM, it is very important to understand that the PLM method has a relatively high detection limit for asbestos (about 1%), and that other microscopic techniques have shown that many soil-type samples that are below the limit of

TABLE 1. EXAMPLE PLM DATA FOR SOIL AND SOIL-LIKE MEDIA

Location	Detection Frequency	Concentration (%)
Export Plant	49/113	<1% - 10%
Screening Plant	125/301	<1% - 6%
Rainy Creek Road	22/72	<1% - 5%
Residential/commercial properties	56/459	<1% - 10%
Schools	28 / 88	<1% - 15%
Daycare	7 / 16	<1%-1%
Conveyer area	3 / 29	<1% - 2%

detection by PLM do contain high levels of asbestos fibers. For example, Figure 1 is a scanning electron microscope (SEM) image of a soil material that was below the limit of detection by PLM, but which clearly contains high levels of asbestos fibers. EPA is working to develop SEM and other related methods for the analysis of soil, but the methods are not yet sufficiently refined to support quantitative estimates of fiber concentration. Nevertheless, these data support the qualitative conclusion that soils from the site that contain levels above the detection limit by PLM and/or those that contain high levels of asbestos fibers when examined by SEM are sources of potential concern.

3. Disturbance of Contaminated Source Materials can cause a Respiratory Hazard: (Exposure Assessment)

Asbestos fibers in soil or dust are not inherently hazardous to humans if left undisturbed. However, most soils and dusts are subject to disturbance, either now or in the future, by many different types of activities that are common for residents or workers. Through our investigations we have collected substantial data at the site that demonstrate that disturbance of contaminated source materials may lead to the release of asbestos fibers into air.

Figure 1: Scanning Electron Micrograph (SEM) image of an asbestos bundle observed in a sample reported as "non-detect" by Polarized Light Microscopy (PLM). USGS - Denver

Studies at the Export Plant and the Screening Plant

The initial investigation of potential exposure to asbestos fibers in air during activities that might disturb asbestos-contaminated source material was conducted at the Export Plant and the Screening Plant during spring and summer, 2000. Two EPA workers at each location were fitted with protective equipment and personal air samplers to measure fiber concentrations that occurred directly in the breathing zone. The workers then engaged in routine activities consistent with ongoing work practices at the site. These activities included sweeping floors and organizing material stored in an on-site warehouse. The samples were analyzed by transmission electron microscopy (TEM) using ISO 10312 counting rules. The results are shown in Table 2, stratified according to fiber diameter and length. As seen, concentrations above the OSHA occupational limit of 0.1 f/cc were observed

TABLE 2 TEM RESULTS FOR PERSONAL AIR SAMPLES AT THE EXPORT AND SCREENING PLANTS

Location	Activity	TEM Amphibole Fiber Concentration (f/cc)			
		d > 0.5	d < 0.5 l = 0.5-5	d < 0.5 l = 5-10	d < 0.5 l > 10
Export Plant	Sweeping floors	0.323	0.323	< 0.16	< 0.16

	Moving bags, sweeping floor	1.014	0.507	0.507	0.338
Screenin g Plant	Sweeping floor	0.222	0.259	0.352	0.111
	Bagging soil, sweeping floor	1.222	< 0.61	3.055	1.222

d = fiber diameter (μm)
l = fiber length (μm)

for most size classes. This demonstrates that, in the presence of contaminated soil and dust, routine activities can generate very high concentrations of asbestos fibers in air.

As a consequence of this initial finding, EPA collected a number of additional personal air samples for workers engaged in removal activities at the screening plant. The W.R. Grace company collected similar personal air samples for workers engaged in removal activities at the export plant. All of these samples were analyzed by PCM, and the results are summarized below:

Location	**Detection Frequency**	**PCM Fiber Concentration (f/cc)**		**N > 0.1 f/cc**
		Average	**Maximum**	
Screenin g Plant	205 / 259	0.070 (a)	1.72	41
Export Plant	157 / 186	0.140 (b)	1.60	69

(a) Non-detects evaluated by assuming a value equal to the Limit of Detection (sensitivity)
(b) Limit of detection not reported; non-detects evaluated by assuming a value of zero

As seen, fibers were detected in a majority of air samples, with many samples well in excess of the OSHA PEL of 0.1 f/cc for an 8 hour workday. These data further establish that activities which disturb contaminated source materials are likely to release high concentrations of fibers into the surrounding air.

Studies in Area Residences (Phase 2 Investigation)

Disturbance of contaminated source materials with resultant exposure to fibers in air may occur not only at the former vermiculite processing facilities, but also in people's residences. In order to investigate the potential for this type of exposure, we are currently performing a Phase 2 investigation. The design of this investigation is presented in the *Phase 2 Sampling and Quality Assurance Project Plan (Revision 0) For Libby, Montana* (USEPA 2001). In brief, personal air monitors are used to measure the concentration of asbestos fibers in the breathing zone of people engaged in a series of scenarios that involved routine and special activities in the home, as follows:

Scenario 1: Routine household activities
Scenario 2: Active cleaning activities (dusting, sweeping, vacuuming, etc)
Scenario 3: Simulated remodeling (direct contact with vermiculite insulation)

Air samples are also collected during the activities using stationary air monitors located in the home. Both personal and stationary air samples collected during these activities are analyzed both by PCM and by TEM. Although Phase 2 sampling and analysis activities are not yet complete, preliminary data are available. These preliminary data (based on samples above the detection limit only) are summarized in Table 3 and are shown graphically in Figure 2. For ease of comparison, the values for TEM samples are presented as estimated PCM-equivalents, calculated by summation of the concentrations of all bin sizes that contain fibers likely to be included in a PCM count. Inspection of this Figure reveals the following main points:

a) Concentrations measured by personal air samplers tended to be higher than for stationary air monitors located in the house, supporting the conclusion that human activities that disturb asbestos fibers can result in local elevations in fiber concentration that are not well captured by whole-house monitoring.

b) Concentration values were substantially higher during active cleaning activities (scenario 2) than during routine household activities (scenario 1). Likewise, levels were even higher when activities included disturbance of vermiculite insulation (scenario 3).

c) Elevations are detectable both by PCM and TEM analysis. In many cases, the concentrations of fibers estimated by PCM are higher than by TEM, suggesting that some (but not all) of the fibers detected by PCM are non-asbestos.

TABLE 3 MEAN FIBER CONCENTRATIONS MEASURED DURING PHASE 2

Phase 2 Scenario	Sample Type	Mean Asbestos Concentration (f/cc) (a)	
		PCM	TEM PCME (b)
Scenario 1 (Routine activities)	Stationary	0.006	0.001
	Personal	0.008	0.001
Scenario 2 (active cleaning)	Stationary	0.037	0.013
	Personal	0.122	0.033
Scenario 3 (simulated remodeling)	Stationary	0.079	0.235
	Personal	0.332	0.557

(a) Values are the means of non-zero samples that were above the limit of detection
(b) The concentration shown is an approximation of the PCM-equivalent (PCME) concentration, calculated as the sum of three size bins: d < 0.5 and l = 5-10, d < 0.5 and l > 10, and d > 0.5. This third bin was included because the fibers in this bin are mainly long (l > 5), and all have an aspect ratio greater than 5/1.

<u>Studies at Rainy Creek Road</u>

A third study was conducted by collecting air samples from locations along Rainy Creek Road. As noted above, the soil of Rainy Creek Road is known to contain asbestos at concentrations up to 5% at some locations, and these fibers may be disturbed and resuspended in air by vehicular traffic along the road. The results are summarized in Table 4. As seen, concentration levels of asbestos fibers are lower than for the other locations and scenarios described above, but the values shown represent long-term average concentrations resulting from short releases produced by passing vehicles, followed by longer intervals with low release when no vehicle is passing. Thus, the levels are clearly elevated compared to background, and indicate that vehicle traffic on an asbestos contaminated roadway is a source of potential concern.

TABLE 4 AIR SAMPLE RESULTS FOR RAINY CREEK ROAD

Analytical method	Fiber size class	Concentration in Air (f/cc)	
		Average(a)	Maximum
TEM (ISO 10312)	d > 0.5 AR > 5/1	0.0005	0.0096
	d < 0.5 l = 0.5-5	0.0002	0.0116
	d < 0.5 l = 5-10	0.0001	0.0050
	d < 0.5 l > 10	0.0001	0.0029
PCM	l > 5 AR > 3/1	0.0013	0.019

d = fiber diameter (um)
l = fiber length (um)
AR = aspect ratio (l/d)
(a) Average concentration for values calculated using zero for non-detects.

Taken together, the *data from these three different lines of investigation all strongly support the concept that active disturbance of asbestos-contaminated source materials can result in high concentrations of asbestos fibers in the breathing zone*.

4. Fiber Concentrations in Air are of Human Health Concern (Risk Characterization)

Exceedences of OSHA Standard

As noted above, multiple air samples collected during investigations to assess the effect of source disturbance have exceeded the OSHA occupational guideline of 0.1 f/cc. Occupational guidelines for asbestos are not protective for non-asbestos workers or residents for several reasons USEPA, 1995). Occupational guidelines are intended to protect workers who, a) are fully aware of the hazards of the occupational environment, b) have specific training and access to protective equipment such as respirators and/or protective clothing and, c) actively participate in medical monitoring. Never-the-less, occupational data acquired at the site are summarized in Table 5. These data demonstrate that a variety of different types of activities at a variety of different locations within Libby have the potential to generate hazardous airborne levels of asbestos.

TABLE 5 EXCEEDENCES OF OSHA STANDARD

Location	Activity	Exceedance Frequency (a)	
		PCM	TEM-PCME
Export Plant	Sweeping, moving		2 / 2
	Removal activities	69 / 186	
Screening plant	Sweeping, moving		2 / 2

	Removal activities	42 / 261	
Rainy Creek Road	Vehicular traffic	0 / 87	0 / 133
Residences (Phase 2)	Routine	0 / 8	0 / 19
	Active cleaning	24 / 115	1 / 117
	Simulated remodeling	12 / 24	9 / 24

(a) Frequency based on personal air samples for all scenarios except Rainy Creek Road, which is based on stationary air samples. All Non-detects evaluated by assuming a value of zero.

Screening Level Cancer Risk Estimates

A number of alternative methods have been developed for estimating the risk of lung cancer and/or mesothelioma in humans from inhalation of asbestos fibers. Risk models developed by USEPA (1986), NIOSH (Stayner et al. 1997), and NRC (1984) all take the following form:

Risk = Concentration (PCM f/cc) * Slope factor (risk per PCM f/cc)

The slope factors derived by these different groups are presented below:

Group	**Slope factor (Risk per f/cc)**
EPA (1986)	0.23
Stayner et al. (1997)	0.078
NRC (1984)	0.154

These slope factors are intended to apply to long-term average concentrations rather than peak concentrations that occur during short-term activities, so application of the basic risk model to the evaluation of intermittent exposures requires a term to account for the less than continuous nature of the exposure:

Risk = Concentration (PCM f/cc) * TWF * Slope Factor (risk per PCM f/cc)

where:

TWF = Time-weighting factor to account for less-than-lifetime exposure via the activity being evaluated. For example, if an activity were performed for 1 hour per day, three days per week for 50 years, the TWF would be 1/24*3/7*50/70 = 0.0128.

EPA is in the process of obtaining site-specific data on the likely exposure frequency and duration (TWF) for the various scenarios of potential concern, but plausible screening level exposure frequencies and durations are shown in Table 6. These values are generally similar to the RME exposure assumptions commonly employed for residents and workers at other Superfund sites, except that the exposure duration for residents (40 years) was assumed to be somewhat higher than the normal default (30 years) due to greater stability of the Libby community.

TABLE 6 SCREENING LEVEL EXPOSURE PARAMETERS

Location	Activity	Exposure Assumptions				
		Population	hrs/dy	days/yr	yrs	TWF
Area residences	Scenario 1 (Routine)	Residents	16	350	40	0.3653
	Scenario 2 (Cleaning)	Residents	2	50	40	0.0065
	Scenario 3 (Remodeling)	Contractor	8	250	25	0.0815
Screening plant	Removal	Contractor	8	250	25	0.0815
	Sweeping	Contractor	8	250	25	0.0815
Export plant	Removal	Contractor	8	250	25	0.0815
	Sweeping	Contractor	8	250	25	0.0815
Rainy Creek Rd	Vehicle traffic	Nearby resident	24	350	40	0.5479

Concentration values used in these calculations are all based on measured values in site samples. Because detection limits were rather high in some samples (due to a small volume of air and/or a small number of grid openings counted), all non-detect values were evaluated by assigning a value of zero. Note that this approach is likely to underestimate the true level of risk, although the magnitude of the underestimation cannot be quantified. When samples were counted using ISO 10312 rules, the concentration of PCM fibers were estimated by summing all fibers longer than 5 um and thinner than 0.5 μm, plus all fibers thicker than 0.5 μm. This approach might tend to overestimate the concentration of PCME fibers since some fibers that are thinner than 0.5 μm will be too thin to detect by PCM. However, this is not likely to cause a significant overestimation because a majority of fibers detected at the site tend to be thicker than 0.25 um (visible by PCM). Fibers thicker than 0.5 μm were included in the estimate because most of the fibers in this bin are long and meet the definition of a PCM fiber. In most cases the samples used for risk evaluation are personal air samples, and thus represent the fiber concentration in the breathing zone of the exposed person. For samples along Rainy Creek Road, stationary air sampler data were employed to estimate the exposure of people who live near the road (now or in the future).

FIGURE 3: ESTIMATED SCREENING-LEVEL CANCER RISK ESTIMATES

The screening level risk estimates are shown in Figure 3. The results in the upper panel are based on the average values across samples within a group (e.g., the mean of all Phase 2 Scenario 2 personal air data), while the lower panel shows the results for the maximum value within a group (e.g., the highest Phase 2 Scenario 2 personal air value obtained). Thus, the upper panel yields an overview of the risks that may be "typical" for the scenarios evaluated, while the lower panel reflects the risks at the most contaminated sub-locations.

As seen, the estimated risks exceed EPA's usual risk range of 1E-04 (shown by the horizontal dashed lines) in a number of cases based on average values, and in nearly all cases based on maximum values. In some cases, the estimated level risks are very high, exceeding the risk range by two or more orders of magnitude. Thus, even though these risk estimates should be considered screening level and may not be highly accurate, the results nevertheless strongly indicate that exposure to fibers released to air by disturbance of contaminated source materials may be of substantial human health concern.

An alternative risk model is currently under development by the USEPA (Berman and Crump, 1999). This risk model seeks to account for apparent differences in lung cancer risk as a function of fiber size and type. Although this risk model has not yet been peer reviewed, it is potentially important because fiber toxicity is expected to vary as a function of fiber length with longer fibers (greater than 10 μm) displaying considerably greater toxicity than shorter fibers (5-10 μm) in unexposed individuals. Thus, it is possible that actual cancer risks presented here may be underestimated using the EPA, NRC, and/or NIOSH slope factors, since these are based on exposures where long fibers were likely to be relatively infrequent.

In addition to increased cancer risks, Libby residents have 40-60 times the national rate of asbestosis (placing Lincoln county, Montana among the top ten counties for this condition in the country). The cancer risks estimated herein do not address this condition or other non-malignant asbestos-related conditions (i.e., asbestos-related pleural disease) recently found to be occurring among a large number of Libby residents. Asbestos exposure, as evidenced by non-malignant chest radiographic abnormalities, is also associated with an increased lifetime risk of lung cancer, especially among smokers. The models used to estimate cancer risk do not account for increased risk as a result of prior lung disease. Thus risks in Libby may be significantly higher as a result of historical exposure.

V CONCLUSIONS

Asbestos contamination exists in soil, raw ore, ore concentrate, and other soil-like media at multiple locations in and around the community of Libby. If these contaminated sources are disturbed by human activities, fibers are likely to be released to air. The concentration levels released to air depend on the concentration of fibers in the source material and on the nature of the disturbance. Risks are proportional to the concentration of fibers in air and the frequency and duration of exposure. While data are not yet sufficient to perform reliable human-health risk evaluations for all sources and all types of disturbance, it is apparent that releases of fiber concentrations higher than the OSHA PEL may occur in some cases, and that health risks to residents and workers exceed the risk range usually used by EPA for at least some locations. The occurrence of non-occupational asbestos-related disease among Libby residents is extremely unusual, and has not been associated with asbestos mines elsewhere, suggesting either very high and prolonged environmental exposures and/or increased toxicity of this form of amphibole asbestos. On this basis, I recommend that steps be taken to further identify, quantify, minimize and/or eliminate pathways of human exposure to amphibole asbestos in the vicinity of Libby.

VI REFERENCES

Amandus, H.E., Wheeler, P.E., Jankovic, J., and Tucker, J. 1987a. *The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part I. Exposure estimates*. Am J of Ind. Med 11:1-14.

Amandus, H.E., Althouse, R., Morgan, W.K.C., Sargent, E.N., and Jones, R. 1987b. *The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part III. Radiographic findings.* Am. J. of Ind Med 11:27-37.

Amandus, H.E., and Wheeler, R. 1987c. *The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part II. Mortality*. Am. J. of Ind Med. 11:15-26.

ATSDR 2000. Health Consultation: Mortality from asbestosis in Libby, Montana. CERCLIS No. MT0009083840. December, 12, 2000. DHHS, ATSDR, DHAC; Atlanta, GA.

ATSDR 2001. Preliminary findings of medical testing of individuals potentially exposed to asbestiform minerals associated with vermiculite in Libby, Montana: an interim report for community health planning. February 22, 2001. DHHS, ATSDR; Atlanta, GA.

BOM. 1953. *Vermiculite.* Bureau of Mines Information Circular 7668.

Cookson, W, De Klerk, N, Musk, AW, et. al. 1986. *The natural history of asbestosis in former crocidolite workers of Wittenoom Gorge.* Am. Rev. Respir. Dis. 133:994-998.

Erlich R, Lilis R, Chan E, Nicholson WJ, Selikoff IJ. 1992. *Long term radiological effects of short term exposure to amosite asbestos among factory workers*. Brit. J. Indust. Med. 49:268-275.

DOI. 1928. *Contributions to Economic Geology Part 1: Metals and Nonmetals Except Fuels*. Department of the Interior, U.S. Geological Survey. Bulletin 805. U.S. Government Printing Office. p. 24-27.

Eschenbach Deposition Exhibit 182.126. Nelson, Ryan & Albert vs. W.R. Grace. *Airborne fiber concentrations in downtown Libby*. W.R. Grace and Company. 62 Whitmore Ave. Cambridge, MA.

Grace. Geologic Map of the Zonolite Open Pit Mine. (Plate 2) Lincoln County, MT. MLSB 000270.

Lockey, J.E., Brooks, S.M., Jarabek, A.M., Khoury, P.R., McKay, R.T. , Carson, A., Morrison, J.A., Wiot, J.F. and Spitz, H.B. 1984. *Pulmonary Changes after Exposure to Vermiculite Contaminated with Fibrous Tremolite.* Am Rev. Respir. Dis.129:952-958.

Hillerdal, G, Henderson, DW. 1997. *Asbestos, asbestosis, pleural plaques and lung cancer*. Scand. J Work Environ. Health 23:93-103.

MacDonald, J.C., McDonald, A.D., Armstrong, B., and Sebastien, P. 1986a. *Cohort study of mortality of vermiculite miners exposed to tremolite*. Brit. J. of Ind. Med 43:436-444.

MacDonald, J.C., Sebastien, P, and Armstrong, B. 1986b. *Radiological survey of past and present vermiculite miners exposed to tremolite.* Brit. J. of Ind. Med 43:445-449.

Miller, A, Teirstein AS, Selikoff IJ. 1983. *Ventilatory failure due to asbestos pleurisy*. Amer. J. Med. 75:911-919.

MacDonald, J.C., McDonald, A.D., Armstrong, B., and Sebastien, P. 1986. *Cohort study of mortality of vermiculite miners exposed to tremolite*. Brit. J. of Ind. Med 43:436-444.

MRI. 1982. *Collection analysis, and characterization of vermiculite samples for fiber content and asbestos contamination. Final report*. Washington, DC; U.S. Environmental Protection Agency. Contract No. 68-01-5915

NRC. 1984. *Asbestiform Fibers - Non-occupational Health Risks*. National Research Council, Committee on Non-Occupational Health Risk.

Rosenstock, L. 1991. *Roentgenographic manifestations and pulmonary function effects of asbestos-induced pleural disease*. Toxicology and Indust. Health 7:81-87.

OSHA. 1994. *Occupational Exposure to Asbestos.* Federal Register 59(153):40978-82.

Stayner L, Smith R, Bailer J, Gilbert S, Steenland K, Dement J, Brown D, Lemon R. 1997. *Exposure-response analysis of risk of respiratory disease associated with occupational exposure to chrysotile asbestos*. Occup. Environ. Med. 54:646-652.

USEPA. 1986. *Airborne Asbestos Health Assessment Update*. U.S. Environmental Protection Agency, Office of Research and Development. Washington DC. EPA/600/8-84/003F. June 1986.

USEPA. 1995. Regional Technical Position Paper on the Proper Use of Occupational Health Standards for Superfund Baseline Risk Assessments. February 13, 1995.

USEPA. 1999. Interim methodology for Conducting Risk Assessment at Asbestos Superfund Sites. parts 1 and 2. U.S. Environmental protection Agency Region 9. Prepared by D. W. Berman (Aeolus, Inc.) and K. Crump (ICF Kaiser Engineers, Inc.) Feb. 15, 1999.

USEPA. 2000. *Sampling and Quality Assurance project Plan (Revision 1) for Libby, MT*. Prepared by USEPA Region 8 with technical support from ISSI Consulting Group.

USEPA. 2001. *Phase 2 Sampling and Quality Assurance Project Plan (Revision 0) For Libby, Montana. Environmental Monitoring for Asbestos. Evaluation of Exposure to Airborne Asbestos Fibers During Routine and Special Activities*. Prepared by USEPA Region 8 with technical support from Syracuse Research Corporation.

Weis, C.P. 2000. *Residual mineral fiber contamination at the former W.R. Grace Screening Plant and Export Plant poses an imminent and substantial endangerment to public health*. Memorandum from Christopher P. Weis, USEPA Regional Toxicologist, to Paul Peronard, USEPA On-Scene Coordinator for the Libby Asbestos Site. Dated 5/10/2000.

Whitehouse, A. 2000. Presentation minutes from Cincinnati review meeting hosted by EPA and ATSDR. February 22-23, 2000.